National Aeronautics and Space Administration

PLANETARY PROTECTION ADVISORY COMMITTEE

February 8–9, 2005
NASA Headquarters
Washington, DC

MEETING REPORT

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John D. Rummel	Norine E. Noonan
Executive Secretary	Chair

PLANETARY PROTECTION ADVISORY COMMITTEE (PPAC)
NASA Headquarters
Washington, DC
February 8–9, 2005

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Meeting Report Prepared By:
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Tuesday, February 8

Welcome and Meeting Overview

Dr. Norine Noonan, chair of the PPAC, called the meeting to order at 8:38 a.m. and welcomed the committee members, representatives from Federal agencies and international representatives, and other meeting attendees. After introducing Mr. Al Diaz, Associate Administrator, Science Mission Directorate (SMD), Dr. Noonan asked the members to introduce themselves to Mr. Diaz and mention their areas of expertise. Dr. Noonan noted to Mr. Diaz that the diverse composition of the committee reflects the range of disciplines relevant to planetary protection issues.

Science Mission Directorate Introduction

Mr. Diaz welcomed the members and spoke about recent triumphs in space exploration missions, including the Mars Exploration Rovers (MER) and the Cassini/Huygens mission. In the recently released President's budget request for fiscal year (FY) 2006, NASA science has an increasing budget, while most civilian program budgets are declining. The NASA science budget will increase by 25 percent. In 2010, the science budget will be at about 38 percent of the total NASA budget and will be the largest single item in it. Mr. Diaz expressed concern about the possibility that disagreements within the science or NASA communities about programmatic decisions could undermine the political consensus that supports this budget appropriation for NASA science. The SMD will continue to have both the PPAC and a NASA Science Advisory Committee as its two advisory committees that are formally chartered under the Federal Advisory Committee Act (FACA).

Planetary Protection Program Update and Committee Discussion

Dr. John Rummel, NASA Planetary Protection Officer and the Executive Secretary of the PPAC, reviewed the top-level NASA organizational structure after the 2004 transformation, including the division structure within the SMD. By NASA Policy Directive, Dr. Rummel reports to the Associate Administrator of the SMD. He explained the scope that the PPAC has been given to cover all NASA space missions, whether or not they are managed from within the SMD. There is a plan to write a document on planetary protection for human exploration missions, once the planning for human exploration has solidified. Dr. Rummel addressed committee questions about the working relationship between the Exploration Systems Mission Directorate (ESMD) and SMD with respect to mission objectives and planning. Dr. Noonan agreed that the relationships among the PPAC, SMD, and the other mission directorates are a subject on which the PPAC needs to stay current. NASA staff commented on the close working relations between the Robotic Lunar Exploration Program (RLEP) office within SMD and the requirements division in ESMD, which formulates the requirements for both RLEP and human lunar exploration.

Dr. Rummel described the strategic roadmapping process now in progress as an Agency-wide activity. There will be 13 strategic roadmaps responding to the 18 Agency-level strategic objectives and 15 capability (technology) roadmaps. Dr. Laurie Zoloth asked about the status of NASA-sponsored research on human health and safety issues using animal models. Dr. Rummel said that the animal model research, which has connections with the International Space Station

(ISS), was moved to the ESMD and may be redirected as part of priority-setting in support of the Exploration Initiative. Dr. Zoloth explained that her concern was related to the issue of the informed consent requirement for testing with animal models prior to human exposure, if exploration is understood as a scientific research effort. The requirement may be different if exploration is viewed as a military and security operation. NASA staff commented that there has been a change in the animal modeling research on the ISS from a basic science focus to applied research in support of exploration objectives. However, the Institutional Review Board (IRB) requirements for prior review and approval of research have been kept. Returning to the subject of strategic roadmapping, Dr. Rummel presented the membership of the Mars Robotic and Human Exploration Strategic Roadmap Committee.

To support the FY 2006 budget request, NASA has released a guidance document, *The New Age of Exploration: NASA's Direction for 2005 and Beyond*. (PDF version available on line at http://www.nasa.gov/pdf/107490main_FY06_Direction.pdf .) This document includes the 18 NASA strategic objectives. Dr. Rummel answered committee questions about the prospect of continued fungibility of appropriated budget lines across mission directorate budgets. He reviewed the budget changes for programs within the SMD, as proposed in the FY 2006 budget request. With respect to the issue of informed consent prior to human exposure, he noted that the Chief Medical Officer for NASA has been named the Independent Technical Authority (ITA) for the Human Systems Research and Technology program in the ESMD.

Dr. Rummel described recent discoveries by the Mars rovers and the status of the Japanese Hayabusa spacecraft, which recently completed an Earth swing-by on its mission to collect and return a sample from the asteroid Itokawa. He reviewed several recent popular science articles relevant to planetary protection topics, significant planetary protection events since the June 2004 PPAC meeting, and planetary protection events planned for the coming year. In April 2005, the planetary protection course for practitioners will be offered for a third time. This offering will be in Santa Cruz, California. A National Research Council (NRC) study committee is completing an update to the 1992 study on forward contamination of Mars. (See presentation below by Pamela Whitney, the NRC Study Director.)

Next, Dr. Rummel discussed with the PPAC a draft protocol for the Mars Sample Receiving Facility (SRF) and the June 1999 draft planetary protection requirements for a Mars Sample Return (MSR) mission. The SRF protocol will build upon and extend the *Draft Test Protocol for Detecting Possible Biohazards in Martian Samples Returned to Earth* (NASA/CP–2002–211842). The draft MSR planetary protection requirements cover both forward contamination (outbound phase of the mission) and back contamination (return phase). The draft requirements for a Category IV lander includes potential alternatives to the COSPAR Category IV.B requirement (Viking-class dry heat sterilization after reduction of total spacecraft bioburden). One alternative requires that the project demonstrate that the probability of a single viable Earth organism contaminating the samples returned to Earth within each sample return canister is less than 10^{-2}. A second option would be for the project to demonstrate an effective way of marking any Earth organism that made the round-trip and returned with the MSR sample. Dr. Rummel explained that the purpose of giving the project these options was to provide the project engineers with a basis for project design work. After some initial discussion by the PPAC of the first option to Category IV.B sterilization, Dr. Rummel presented and discussed the draft requirements on back contamination. One of these requires that the sample canisters and Earth Entry Vehicle (EEV) for sample return should be designed to have structural integrity and sealing sufficient to reduce the probability of releasing a ≥ 0.2 μm particle into Earth's biosphere to less than 10^{-6}. Dr. Rummel described how this and the other draft requirements were related to each other in covering MSR operations up to delivery of the returned sample to the SRF.

Discussion: PPAC members commented on the difficulty in translating the technical language of the draft requirements for MSR into language that will communicate clearly to the lay public. After discussion, there was general agreement that the language for presenting standards to engineers should be different from the way the context and rationale for the standards are communicated for public comprehension.

Current Status of ESA Missions and Cassini/Huygens

Dr. Gerhard Schwehm, the ESA representative to the PPAC, updated the committee on ESA missions including results from Mars Express and Cassini-Huygens. The Rosetta spacecraft has its first Earth flyby in March 2005. ESA is seeking an extension for the SMART I mission. Otherwise, its half-year science phase under current mission funding will end at the end of February 2005. In the past year, a working group was formed to prepare a proposal for a standard on planetary protection to be issued by the European Co-operation for Space Standardization (ECSS). If approved, this will be a general standard for the European space industry. A draft will be available in March 2005, at which time the relevant ECSS committees will begin their review.

The preparation phase of the ESA Exploration Programme, also called Aurora, which is under the Director for Human Spaceflight and Exploration, was funded in September 2004. Industrial studies on the ESA ExoMars project are in progress. Results from the first year of orbital operations by the Mars Express spacecraft will be presented at the first Mars Express Science Conference on February 21–25, 2005. More than 200 abstracts were received, and the conference will include a roundtable discussion on future European participation in the exploration of Mars.

Dr. Schwehm highlighted some of the science results from the Mars Express instruments and from Cassini-Huygens. Cassini-Huygens is a joint ESA–NASA project that began in 1982 with a proposal to ESA. Dr. Schwehm described the successes in international collaboration during the project's development period, which involved teams from several countries. He noted that the recent U.S. rules on International Traffic in Arms Regulations (ITAR) would make similar collaborations far more difficult now. He described the sequence of events during the entry, descent, and landing of the Huygens probe and during its operational life on the surface of Titan. Although only 72 minutes of Huygens data after landing was received and relayed by the Cassini spacecraft, the entire 5 hours of data was received via direct transmission from the Huygens probe to Earth. Dr. Schwehm reviewed the imagery and preliminary interpretation of data from the Huygens instruments. Data analysis is continuing. The pebble-like features in the images from the Titan surface are thought to be primarily water ice. Titan appears to have a weather cycle in which methane is the working fluid.

Mars Program Overview

Mr. Doug McCuistion, NASA Program Director for the Mars Exploration Program, briefed the PPAC. Proposals are being prepared for another extension of the MER mission beyond June 2005. The Odyssey orbiter, acting as an ultrahigh frequency (UHF) relay, is providing 98 percent of the data transmission from MER. Mr. McCuistion discussed the science implications of some of the recent MER results. The radar antenna for the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) instrument on Mars Express will be deployed on May 2. The Mars Reconnaissance Orbiter (MRO) remains on schedule for launch in August 2005. The preliminary design review (PDR) for the Phoenix Scout mission is in March 2005, with confirmation review in April. An award is anticipated soon for the contract to build the Mars

Telecommunications Orbiter (MTO). Instrument selection has been completed for the Mars Science Laboratory (MSL).

Mr. McCuistion said that the "Search for Evidence of Past Life" exploration pathway is now being emphasized for Next Decade planning. He reviewed the two strategic objectives that will be covered by the Robotic and Human Mars Exploration Strategic Roadmap (Mars SRM). Several results from the first Mars SRM committee meeting have relevance to planetary protection and the PPAC. In particular, that committee is considering: (1) multiple MSL rovers, perhaps over a series of missions; (2) common architecture/hardware platforms for rovers, telecommunications orbiters, and major subsystems such as an entry, descent, and landing (EDL) system; (3) human precursor missions to demonstrate capabilities (technology) needed for future human missions; and (4) scenarios for human missions to Mars. Mr. McCuistion described some of the principal technological challenges in preparing for human missions on the Mars surface, such as an EDL system appropriate for 40 tons of landed mass, compared with the current limit of 2 tons. Dr. Eugene Levy said that a critical issue for the PPAC to address is how far the search for extant life should be pursued before Mars is contaminated by human, or even robotic, missions. The PPAC discussed the relative roles of robotic and human missions. Other topics discussed with Mr. McCuistion included the role of Crew Exploration Vehicle (CEV) development and lunar exploration as preparation for human missions to Mars.

The Mars Exploration Program Analysis Group (MEPAG) has defined a set of human precursor requirements (questions to be answered prior to undertaking human missions to Mars). Some of these requirements can be addressed by missions planned for the robotic science program. Others will need to be addressed through human precursor test bed missions, which will focus on capability demonstration rather than science objectives. An analysis is underway to determine the types of platforms and missions (orbiters, lander/rovers, sample return missions) required to meet all of the Mars human precursor requirements not covered by the planned robotic science program. Mr. McCuistion said that most of the activities to address the Mars human precursor requirements have planetary protection implications. He also discussed his thoughts on planetary protection considerations relevant to decisions on common platforms for missions such as MSL and MSR.

Next, Mr. McCuistion reviewed recent work on SRF planning, including the industry studies previously briefed to the PPAC and recent cost estimates. The team working on Mars Returned Sample Handing (MRSH) and the SRF has been expanded. Because of its complexity and cost, said Mr. McCuistion, SRF development should be run like a NASA flight project. The flight segment (MSR) and ground segment (SRF) of planning for samples returned from Mars are now under a single program manager at Jet Propulsion Laboratory (JPL). The MEPAG will be tasked to set up a Science Steering Group to develop sample return requirements for activities both on the Mars surface and at the SRF. In concluding his briefing, Mr. McCuistion described some of the interfaces being developed among various groups inside and outside NASA to define the interrelationships among robotic Mars science missions, human Mars missions, and the lunar exploration program.

Discussion: Dr. Noonan commented that the PPAC was pleased to see a renewed effort on planning and preparation for the SRF. She encouraged the program to take the time necessary to think through the integration required across the mission directorates, as well as across the lunar and Mars programs. Dr. George Robinson asked how, and if, military and other national strategic interests in some of the relevant technologies were being coordinated with the integration of NASA's science and engineering objectives, as those interests might influence planetary protection decisions and approaches.

Solar System Exploration Overview

Mr. Andrew Dantzler, Acting Director of the Solar System Division within the SMD, began with a review of current missions and other activities in the division. These include nine operating missions located throughout the solar system and three missions to be launched in the next 18 months. Missions in the planning and preparation phases include Kepler, the Lunar Reconnaissance Orbiter (LRO) as the first RLEP mission, a second RLEP mission, Phoenix Scout, MSL, the eleventh and twelfth missions in the Discovery Program, and a second mission in the New Frontiers Program. Although the Huygens probe has completed its operational life on Titan, the Cassini spacecraft still has 3.5 years remaining in its primary science mission.

With respect to the Jupiter Icy Moons Orbiter (JIMO) mission, the use of nuclear electric power for the spacecraft has been deferred. Instead, Project Prometheus (the NASA program to develop nuclear reactor energy for spacecraft) will likely proceed with a separate demonstration project for nuclear electric power. Mr. Dantzler presented the current timeline for the RLEP and described the six instruments competitively selected for LRO.

The MESSENGER spacecraft is proceeding well on its transit to Mercury and has performed all flight maneuvers successfully. Deep Impact, which launched on January 12, will have its encounter with a nearby comet on July 4, 2005. The sample return from the Stardust mission to comet Wild is on schedule for January 2006. The Dawn mission to fly by two asteroids using an ion propulsion engine is on track for launch in June 2006. Despite the crash landing of the sample return canister from Genesis, all of its 19 planned scientific measurements on solar wind particles can be done with the recovered sample.

An independent review team assessed the readiness of the New Horizons mission to Pluto and the Kuiper Belt. and gave its final report on February 2. The development schedule has no reserve remaining. However, Los Alamos National Laboratory has found enough plutonium for the radioisotope thermoelectric generators (RTGs) to make a 2007 backup date viable, if the January 2006 launch window cannot be met.

Only one proposal was selected for phase A in the eleventh Discovery mission solicitation. The downselect for the second New Frontiers mission will be in June 2005, and both candidate missions have planetary protection considerations.

Preventing the Forward Contamination of Mars (NRC)

Dr. Pamela Whitney, study director for the NRC committee on preventing the forward contamination of Mars, gave an update on the study's status. She reviewed the statement of task and committee membership. The report, which will update the 1992 report on this topic, is currently being prepared for the NRC peer review process. Dr. Whitney expects that a prepublication version will be ready for release in late March or early April. However, the timing is subject to how the report fares in the peer review. In response to a PPAC question, Dr. Whitney said that the report does not address issues of humans on Mars. Dr. Levy commented that a study is needed on what would count as sufficient understanding of the martian environment to provide a basis for deciding on adequate planetary protection measures.

Mars Science Laboratory Mission and Investigations

Dr. Michael Meyer, MSL Program Scientist, briefed the PPAC on the status of the MSL project. Launch is currently scheduled for 2009. The MSL science objective is to quantitatively assess a local region on the surface of Mars as a potential habitat for life, past or present. The science floor has three broad goals: to assess the biological potential of at least one target environment, to characterize the geology of the landing region at multiple spatial scales, and to investigate planetary processes relevant to past habitability. The recent selection of investigations/ instruments proposed in response to a competitive Announcement of Opportunity (AO) was based on these three goals, plus two science objectives: characterizing the surface radiation environment and investigating the presence of known toxic materials as part of the geochemical surveys. The selected science investigations fall into four groups: analytical laboratory investigations, remote sensing investigations, contact instrument investigations, and others. MSL will also have two instruments, contributed by international partners, which were not competed. Dr. Meyer described the individual instruments, their capabilities, and their mapping against the more detailed set of MSL objectives recommended by the MSL Project Science Integration Group (PSIG) in 2003. All of these more detailed objectives, which elaborate the three broad goals, can be met with the selected suite of instruments.

The current rover design is smaller than the October 2003 concept but larger than a MER. Building on the MER experience, data communications will use UHF transmission to a relay orbiter, not direct-to-Earth transmission. Samples for the analytical laboratory investigations will probably be split among instruments, rather than taking sequential samples for different instruments.

Discussion: Dr. Noonan said that the PPAC was interested in interactions among the instruments from a planetary protection perspective. In response, Dr. Meyer described a potential scenario for how instruments would be used in sequence to investigating areas and samples of interest. The committee and staff discussed the planetary protection issues with avoiding forward contamination and whether parts of the rover could come under the COSPAR Category IV.A requirement, while any part in contact with samples would come under Category IV.B. Another issue discussed was whether the planetary protection issues are just forward contamination or might include potential round-trip contamination if MSL caches samples for MSR. After discussion, there was general agreement that ground heating in a martian special region, which might melt subsurface ice, is not an issue if the rover is intact and operating as planned. Dr. Meyer discussed the risk issues in different approaches to fetching or caching samples for return using a rover, compared with having an integrated rover-and-ascent system collect samples

Committee Discussion

Dr. Noonan led the PPAC in a discussion of the day's briefings and topics that the committee should learn about and discuss at future meetings. In response to questions, Dr. Rummel described the content of the planetary protection practitioners course, which will be offered in Santa Cruz, California, in April. In her summary of issues raised during the day, Dr. Noonan noted the question asked by Dr. Levy about the criteria for completing life detection efforts prior to the forward contamination complications raised by human missions to the surface of Mars. Dr. Carle Pieters said that there is still inadequate integration of sample return efforts with an answer to this question. Dr. Levy suggested that the concern might be stated by PPAC as a dependency of the time frame for sending humans to Mars on the time frame for adequate life detection and assessment of the biological potential of Mars. Mr. Perry Stabekis, who provides technical support to the Office of Planetary Protection, said that the closest thing at present to Dr. Levy's

criteria is the notion of martian special regions. The problem, he said, lies in matching the programmatics for mission objectives with the problem of avoiding forward contamination of special regions. One must be able to go to the special regions to explore them.

Dr. Noonan asked how funding for technology investment in Mars planetary protection had fared in the President's FY 2006 budget request. Dr. Rummel replied that the amount of the Mars technology budget that will go to planetary protection has not been decided yet. Dr. Michael Carr suggested that Dr. Levy's question should be posed at a high level: What are the criteria for deciding that sufficient life detection investigation has been done? The PPAC discussed how a strategy for getting to an answer might be formulated, even if precise criteria cannot be specified now. Also discussed were the difficulty of answering the questions about past or extant life on Mars quickly and the cost and difficulty for Mars missions if a strict planetary protection regime must be continued indefinitely. There was general agreement that a better means of sterilization is needed than dry heat sterilization (Viking-style sterilization).

Dr. Rummel suggested that the PPAC could send a letter to the Robotic and Human Mars Exploration Strategic Roadmap Committee on the planetary protection issues that need to be addressed in that roadmap. He suggested one scenario for how the Mars Exploration Program might evolve to address the life issues over time.

Action Item: Dr. Noonan agreed with the suggestion that the PPAC should send a letter on planetary protection issues to the Robotic and Human Mars Exploration Strategic Roadmap Committee.

Dr. Ron Atlas reminded the PPAC that addressing the surface sterilization issues would still leave the bioburden from bulk contamination, which might be released in a crash. Dr. Carr restated Mr. Stabekis' problem as a conundrum in which missions are restricted by planetary protection concerns from going to exactly those places where signs of past or extant life are most likely to be found. This led to a general discussion of issues in deciding whether and when a Mars mission should go to a special region or avoid it.

Dr. Noonan said that a second issue raised during the day was the necessity of communicating planetary protection concerns in ways that the public can understand, as well as translating fundamental concerns into quantifiable metrics and standards for project engineers. Dr. Susanna Priest agreed and elaborated on the aspects of public trust, the potential for misinterpretation, and the need to understand how wording used in public communications will be interpreted. It is important to be transparent in the message, and transparency may be more important than restricting the content of communications to the point that they are interpreted as a lack of openness.

In answer to a question, Dr. Rummel and Dr. Noonan said that it is in PPAC's purview to advise NASA on experiments that need to be done to address planetary protection issues. Dr. Atlas used the discovery of extremophiles in the environment of deep-ocean thermal vents to initiate a discussion of whether threats to human health from Mars life forms (back contamination) and forward contamination issues could be kept separate or would ultimately converge.

Mars Sample Return Mission and Planning

Dr. Mark Adler, the Pre-Project Manager for MSR at JPL, briefed the PPAC on the history and current status of MSR planning. Formal planning was halted from 2000, when the Office of Management and Budget (OMB) removed MSR funding, until the President's Vision for U.S.

Space Exploration was announced in January 2004. With MSR back in the NASA budget, a Pre-Project activity was established in October 2004. Start of MSR as a project is scheduled for late 2007, with launch in 2013 and sample return to Earth in mid-2016. MER reestablished confidence in NASA's ability to explore the Martian surface, and the rovers found evidence of ancient surface liquid water. The President's vision called out sample return from Mars as prerequisite for sending humans to Mars.

MSR responds to nearly three decades of recommendations in studies by the NRC and other science community authorities. The basic problem in designing and conducting MSR is that the return from Mars to Earth is much more difficult than the outbound trip to the martian surface. Also, the SRF must be built and certified prior to MSR launch. Investment is needed now to prepare for sample handling and analysis after return. The justification for MSR, despite its difficulty, is the information that can only be acquired through in-laboratory analysis. For example, information in samples at the molecular and microscopic scale is only accessible in Earth-based laboratories. Also, the cycle time for experiments that build on results from prior experiments is 6.5 years for in situ investigations (the time to incorporate new results in mission design and send the new instrument to Mars). Typically, just a few months separates successive rounds of experiments on returned samples. Meteorites from Mars found on Earth are not sufficient for laboratory investigations because of three factors, which Dr. Adler summarized as "compromise, constitution, and context." Meteorites are compromised by exposure to deep space and Earth environments. Their composition range is limited to materials that can withstand the shocks of ejection from the Mars surface and entry through the Earth's atmosphere. They provide no information about the geological context from which they originated.

Dr. Adler discussed the importance of site selection for MSR. MRO and Mars Express will contribute information on potential sites, and MSL can identify "best bet" rocks for MSR to sample. The Pre-Project activity for MSR includes planning for the SRF. Also, mobility is now considered essential for the MSR lander. The Focused Technology effort for MSR totals $160 million during FY 2005–FY 2009. Planetary protection is a significant focus for technology development, with particular attention to capabilities for sample isolation and breaking the chain the contact with Mars. MTO in 2009 will include a rendezvous experiment as part of the risk reduction technology demonstration for MSR. Experiments on actual capture of an orbiting object and containment will be done on Earth or in a near-Earth environment, not at Mars. The Pre-Project activity is currently developing a science and engineering feed-forward strategy from MSL (scheduled for launch in 2009). The MSL feed-forward options include tight design coupling, tight operational coupling, and limited coupling. Limited coupling is the level of coupling that always applies from one mission to the next. In the tight design coupling option, the design requirements for the MSL rover allow re-use of the design for MSR, optimizing the cost over both missions. In a tight operational coupling approach, an MSL rover caches samples for MSR and/or delivers them to the MSR lander/ascent system. Even in approaches with limited design or operational coupling, there will be substantial design coupling with respect to cruise architecture, EDL, roving, and science capabilities. Tight operational coupling between an MSL rover and an MSR sample preparation and ascent system may be more applicable to follow-on MSRs, rather than the first sample return mission.

Discussion. The PPAC discussed with Dr. Adler the trades for both for MSL and MSR between avoiding forward contamination of martian special regions and the value of investigating those regions. The trade between in situ investigation capability on the MSR rover versus returning to a site characterized by a previous mission was discussed. Dr. Adler said that studies on these trades are being done. One option being studied is to send two surface assemblies (lander, rover, and/or ascent subsystem). Each assembly would put a sample canister into Mars orbit, even if only one

sample is subsequently captured in orbit and returned. Trade studies are also in progress on the configuration of the surface assembly. For the Earth return, direct entry of the sample capsule is considered the best way to ensure that the sample reaches the Earth's surface as planned. The PPAC discussed concerns about the rover and robotic arm being contaminated by the rocket exhaust from the descent vehicle. Dr. Adler noted that design considerations for MSR, such as this contamination question, potentially could create requirements for the MSL EDL system as the precursor to the MSR system. With respect to timing of MSL and MSR, another consideration is the value of having the MSL mission team available to support MSR operations.

Dr. Adler next discussed the draft planetary protection requirements for sample return in the June 1999 letter from J. Rummel, including both containment (control of back contamination) and cleanliness (control of both forward contamination and risk of round-trip Earth organisms). Dr. Adler emphasized that ways to meet all the planetary protection requirements are not yet known, but he summarized the current implementation strategy for planetary protection. For the cleanliness requirements, technologies are being evaluated for two options: whole spacecraft sterilization and isolation of sample collection from the bulk of the surface assembly. One of Dr. Adler's concerns is that more stringent containment requirements than those in the 1999 letter may become operative during project development. Mr. Stabekis commented that other Federal agencies and international partners were consulted during drafting of the requirements, which should help in constraining addition of more stringent requirements. Dr. Adler then discussed his specific concerns about interpretation of the cleanliness requirements and their technology development and cost implications.

Discussion: Dr. Levy asked if the MSL planetary protection requirements should be stated in terms of risk rather than an event probability. As the environment becomes better understood and characterized, the nature of the risk will be better known. It may be better to focus on mitigating risks as more is learned more about the martian environments, rather than setting requirements that push systems in directions whose risk implications are hard to understand. Other PPAC members added comments on assessing risk and weighing health assessment risks with the risk of destroying the scientific value of a mission. Dr. Rummel noted that another risk is mission cancellation if planetary protection requirements are no longer viewed as credible for dealing with health risks. Dr. Noonan agreed with Dr. Levy's point that moving to a risk requirement rather than a probability requirement could help the project, but it is difficult to see how the term for quantifying the consequences could be added [to relate an event probability to a risk].

Dr. Adler concluded his presentation with a list of dates for draft, preliminary, and final planetary protection requirements to fit effectively with key milestones in the MSR development schedule. He asked for the opportunity to update the PPAC twice a year and interact with the committee on the technology and implementation approaches for MSR. He also asked for the PPAC's assistance in defining an implementable approach for sterilization of materials from Mars, as contingency response to preserve mission success. Dr. Atlas noted that an NRC study is in progress on standards and policies for how clean is safe, in the context of decontaminating public transportation facilities affected by exposure to harmful biological agents.

Sample Receiving Facility: Considerations and Planning

Dr. Adler gave a short presentation on planning and issues for the SRF. The MRS flight project includes the tasks of landing the Earth Entry Vehicle (EEV) with the sample and locating it. From that point, the MRSH project (as the ground segment) has responsibility for transporting the sample to the SRF and for SRF operations. Transfer of the sample from the SRF to the Sample Curation Facility (SCF) at Johnson Space Center (JSC) will depend on the results from the

biohazard testing performed at the SRF in accordance with the final version of the Mars Returned Sample Handling Protocol. The SRF is the major cost component of the MRSH project. Dr. Adler said that the objective of the competitive selection process for the SRF is to select as the implementing contractor the candidate with the most relevant experience and capability. A major challenge is to both protect the sample from Earth contamination (while in the SRF) and protect the Earth's biosystems from contamination by the sample (until it is judged to not constitute a hazard).

Site selection, approval under the National Environmental Policy Act (NEPA), and design and construction of the SRF all have significant schedule risks. Assuming that an SRF definition team is named this year to initiate the process of defining requirements, Dr. Adler estimates that there are only two years of margin in the interval until the MSR project, as currently planned, would return a sample to Earth. If this margin is exhausted and the MSR project remains on its current schedule, the SRF might not be ready in time to receive the returned sample.

Discussion: Dr. Adler and the PPAC members discussed issues in defining a quarantine protocol for the SRF. They also discussed the potential simplification of the process that could result if an existing facility was offered and selected for the SRF. Before adjourning the meeting for the day, Dr. Noonan said that the committee would continue its discussion on MRSH and SRF in the morning.

Wednesday, February 9

Committee Discussion

Dr. Noonan reviewed the previous day's closing discussion on MRS and MRSH. She noted that the schedule for the SRF requires starting now to be ready for returned samples in 2016. The SRF will cost $120–$150 million to build and operate. Dr. Rummel highlighted results from the industry studies of SRF concepts. An SRF Definition Team will draft a protocol for sample handling and the science and curation requirements. It will probably also advise on preferred modes of sterilizing samples for release to investigators. Members and Dr. Rummel discussed issues in selecting the SRF implementing contractor and a site, as well as concerns about public reactions to siting an SRF and to returning samples from Mars. There was general agreement that planetary protection issues need to be communicated in ways that mitigate public fears about sample return. The members also discussed sterilization of the sample before it is returned. Dr. Pieters suggested that it might be better to plan and represent the first MSR as the first in a series of steps. Dr. Robinson suggested that the SRF be considered in the context of preparing for the return of humans from Mars. For example, new regulations might be needed. Members contrasted the lax enforcement in practice of the containment protocols for the Apollo samples from the Moon with the need for clear and rigorous enforcement of protocols for returned martian samples.

Dr. Levy suggested that the PPAC focus on immediate issues needing the committee's attention. He said that a central issue for PPAC attention is the social and political risks in siting and building an SRF. Dr. Zoloth suggested that NASA issue a call for proposals to study ethical, legal, and social issues (ELSI) of sample return, similar to what the Department of Energy has done on ELSI related to the Human Genome Project, bioremediation, and nanotechnology. Dr. Atlas said that NASA must decide whether MSR is intended to seek a sample with the greatest likelihood of evidence for past or extant life or a sample from a site with minimal potential for life and therefore low risk of back contamination. The PPAC continued discussing the appropriate objective for the first MSR with respect to the type of site and type of sample selected.

Dr. Rummel reviewed Dr. Adler's list of requests regarding planetary protection requirements and ways that the PPAC could help. He noted that the NEPA approval process is likely to become intertwined with the MSR planetary protection requirements. The PPAC discussed the types of recommendations it could make that would help the MSR planning and development activities to proceed on the schedule presented by Dr. Adler.

Discussion: Planetary Protection Implementation for Mars Missions

The PPAC turned to consideration of Dr. Rummel's June 14, 2004, letter to the MSR Pre-Project Manager with draft planetary protection requirements. A major point of discussion was the draft provision for relaxing the Category IV.B requirement (Viking-level sterilization for entire spacecraft) if the probability of a single viable Earth organism surviving within each sample return canister could be demonstrated to be less than 10^{-2}. Dr. Rummel asked if this probability number was too stringent or not stringent enough, as a probability of sample contamination that would be an alternative to Category IV.B. He and Mr. Stabekis answered members' questions on the level of cleanliness produced by Category IV.B and the impact on nonaerobic spore populations of alternatives to dry heat sterilization. The members also discussed whether the risk of a returned Earth organism should be considered as a science risk (to be addressed by the mission's science objectives and requirements) or a policy risk (and therefore under the purview of the PPAC). Dr. Carr suggested an approach of balancing risks across the mission, rather than hanging the requirement on the probability of one particular point in the multistep mission sequence.

Dr. Noonan agreed with Dr. Cavanaugh's suggestion that the technique for assaying for organisms needs to be addressed in the round-trip Earth organism provision. This opened a discussion of current assay techniques as providing representative proxies for total bioburden, although they are stated in terms of counts of anaerobic spore formers. The members also discussed the consequences of a false positive with either the Category IV.B standard or an alternative based on viable Earth organisms returning in the sample canister. Dr. Rummel said that one reason he had posed the alternative was to encourage the MSR project to investigate the implications of such a standard for project cleanliness requirements at the engineering level.

After an extensive discussion of how the returned-sample probability limit on a round-trip Earth organism related to the COSPAR requirements stated in other provisions of the letter, the consensus of the PPAC was that the potential alternative should be stated in a section of the requirements separate from the section in which current forward contamination requirements (e.g., the COSPAR IV.B requirement) are stated.

Before the PPAC took its lunch break, Dr. Rummel and the members recognized the service of Dr. Noonan as the first chair of the PPAC. After the lunch break, Dr. Noonan continued the discussion of separating the MSR planetary protection requirements that come directly from COSPAR or existing regulations from the provisions aimed at encouraging the MSR project to ensure that the returned sample is not contaminated by Earth organisms. Dr. Rummel noted that the constraint on Earth organisms in the sample is needed to support a rigorous sample handling protocol once the sample has been returned to Earth. Dr. Atlas said that the round-trip contamination issue should be separated from the question of whether the bulk of the surface assembly could be Category IV.A if the sample collection and handling components are required to meet Category IV.B.

The discussion next turned to the draft requirements on sample containment to prevent inadvertent back contamination. Dr. Rummel noted that the containment probability numbers

stated in the draft requirements letter could affect the feasibility of the mission with available technology. He gave reasons for his choice of particle size limit ($\geq$0.2 μm) and the probability of release ($<10^{-6}$) in the draft requirements. The PPAC discussed whether the particle size limit was too large and whether a gas-tight standard should be used. There was agreement that, at the least, the particle size should be reduced to that of the smallest known viruses. After discussing the other draft requirements for preventing back contamination, Dr. Rummel and the committee discussed the certifications provisions in the draft requirements and the timing for providing a final sample test protocol. The biohazard testing provisions of the sample test protocol were also discussed.

Planning for Future Human Missions I, Human Planning

Dr. Rummel reviewed the community recommendations and current status of planning for humans on Mars, beginning with the May 2002 NRC report, *Safe on Mars*. This report recommended precursor measurements necessary to support human operations on the martian surface. Since then, the priority on measuring radiation (charged particles and neutrons) on the martian surface has been changed to measuring the radiation during the transit in deep space. The NRC committee's recommendations on measurements were divided into the categories of physical environment hazards, chemical environmental hazards, and potential biological environmental hazards. Whether a sample return is required prior to the first human visit should depend on the results of in situ investigations for the presence and concentration of organic carbon. There were also recommendations on programmatic topics, such as rover technologies and robotics, risk standards, and technology. This NRC study also gave priority to the many measurements listed in the 2000 document from MEPAG, which has since been updated.

Dr. Rummel reviewed the work of the MEPAG Mars Human Precursor Science Steering Group (MHP SSG), which began work in June 2004 on a set of human precursor measurement requirements. The approach used by the MHP SSG was to prioritize the risks to humans on a mission to Mars and then select those measurements that would do most to mitigate the priority risks. For example, the group's analysis of the radiation risk to a Mars crew was significant, but the risk from the crew's time on the martian surface was small. The larger portion of the risk was during the transits to and from Mars. The SSG's final report will be presented to the full MEPAG at its meeting on February 16–17, 2005, in Washington, D.C. Dr. Rummel reviewed the SSG's draft list of high-priority risks for a short-stay mission to Mars and the set of measurements recommended to address these risks. The PPAC and Dr. Rummel discussed which of the risks and measurements identified by the MHP SSG, including the measurements related to potential in situ resource utilization (ISRU) on Mars, were most relevant to planetary protection and to concerns within the purview of the PPAC. The committee was also interested in which SSG members were space flight surgeons or had other medical qualifications.

Planning for Future Human Missions II, Planetary Protection

Dr. Rummel discussed planetary protection opportunities and challenges in the context of human exploration of the Moon and Mars, now that both NASA and ESA are formally engaged in planning for human exploration. He reviewed the high-level roadmaps for human exploration from both the NASA ESMD and ESA. Dr. Rummel said that human exploration of Mars will require enhancement of the range of planetary protection measures available and sharpened policy distinctions regarding the nature and location of allowable contamination. He discussed the results from a two-day workshop on Human Exploration and Planetary Protection, held at Pingree Park, Colorado, in 2001. The workshop divided into three workgroups, each addressing one of the three main foci: protecting Mars and science, protecting astronauts and their health, and

protecting the Earth from back contamination. There were also operational subgroups that considered six scenarios for human missions and the potential for forward and back contamination in each scenario. Dr. Rummel reviewed the results from each of the three main workgroups, the operational subgroups, and the overall findings and recommendations from the workshop. He also listed a set of planetary protection topics to be addressed in future workshops, to build on the results from the 2001 workshop. Some of the major milestones in the exploration roadmap will need to have planetary protection milestones and accomplished goals coordinated with them, beginning with the planetary protection requirements for MSR. If the Moon will be used as a test bed for systems and operations to be used on Mars, then implementing Mars-appropriate planetary protection requirements and protocols on those Moon test bed operations will be necessary, even if the requirements are not needed for the lunar surface in itself.

Discussion: Dr. Noonan returned to the question Dr. Pieters had raised earlier in the meeting about the coordination between ESMD and SMD on planetary protection requirements, technology development, and other implementation issues. Dr. Rummel noted that ESMD has been focused on preliminary objectives such as those related to the CEV and the initial robotic lunar missions. The research side of the ESMD has been more fully engaged with understanding and working with the longer-term planetary protection requirements. He explained the NASA policy requirements related to planetary protection that apply across the Agency, not just within the SMD.

Final Discussion and Meeting Wrap-Up

Dr. Rummel said that further work on the MSR forward contamination requirements will be presented to the PPAC at its next meeting. He noted that a NASA Research Announcement (NRA) for Research Opportunities in Space and Earth Sciences (ROSES) has been released that includes planetary protection topics. At some point, a program of directed research may be needed to address planetary protection questions for which appropriate proposals are not received through the ROSES NRAs.

In response to Dr. Robinson, Dr. Rummel described recent interactions with international partners on planetary protection concerns, as well as continuing venues in which international cooperation is occurring. The NRC Committee on Origin and Evolution of Life also continues to be interested in planetary protection issues. Dr. Noonan adjourned the meeting and passed the gavel to the new PPAC chair, Dr. Eugene Levy.

PLANETARY PROTECTION ADVISORY COMMITTEE (PPAC)
NASA Headquarters
Washington, DC
February 8–9, 2005

AGENDA

Day 1—Tuesday, 8 February 2005

8:30am	Welcome and Meeting Overview	Norine Noonan/John Rummel
8:35am	Science Mission Directorate Introduction	Al Diaz, NASA HQ
9:00am	Planetary Protection Program Update/Committee Discussion	J. Rummel
10:00am	Current Status, ESA Missions & Cassini/Huygens	Gerhard Schwehm, ESA
10:30am	Break	
10:45am	Mars Program Overview	Doug McCuistion, NASA HQ
11:15am	Solar System Exploration Overview	Andrew Dantzler, NASA HQ
11:45am	Preventing the Forward Contamination of Mars (NRC)	Pamela Whitney, SSB
12:00pm	Lunch Break	
1:00pm	Mars Science Laboratory Mission and Investigations	Michael Meyer, NASA HQ
2:00pm	Committee Discussion	N. Noonan
3:15pm	Break	
3:30pm	Mars Sample Return Mission and Planning	Mark Adler, JPL
4:30pm	Sample Receiving Facility Considerations and Planning	Mark Adler, JPL
5:15pm	Issues for Committee Deliberation	N. Noonan
5:30pm	Adjourn	
6:30pm	Committee Dinner	701 Pennsylvania Avenue

Day 2—Wednesday, 9 February

8:30am	Introduction to Day 2	N. Noonan/J. Rummel
8:45am	Committee Discussion	N. Noonan
10:15am	Break	
10:30am	Committee Discussion Continues	
12:00pm	Lunch Break	
1:00pm	PP Implementation for Mars Missions Discussion	N. Noonan
2:00pm	Planning for Future Human Missions I, Human Planning	Terri Lomax, NASA HQ
3:00pm	Planning for Future Human Missions II, Planetary Protection	J. Rummel
3:45pm	Committee Discussion and Future Meeting Plans	N. Noonan
4:30pm	Adjourn	

PLANETARY PROTECTION ADVISORY COMMITTEE MEMBERSHIP

Individual Members

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College of Charleston

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Dr. Bobby Braun
Georgia Institute of Technology

Ms. Nancy Ann Budden
Naval Postgraduate School

Dr. Michael H. Carr
U.S. Geological Survey

Dr. Colleen M. Cavanaugh
Harvard University.

Dr. Carolyn S. Griner
Booz Allen Hamilton, Inc.

Dr. Debra L. Hunt
Duke University

Mr. Alan Ladwig
Zero Gravity Corporation

Dr. Debra G. B. Leonard
University of Pennsylvania

Dr. Eugene H. Levy
Rice University

Dr. Carlé M. Pieters
Brown University

Dr. Susanna Hornig Priest
Texas A&M University.

Dr. George S. Robinson, III
Robinson & Associates Law Offices, P.C.

Dr. Laurie Zoloth
Northwestern University

Space Science Advisory Committee Liaison

Dr. Douglas Erwin
National Museum of Natural History, Smithsonian Institution

Agency Representatives

Dr. David Klein
NIAID, National Institutes of Health

Dr. Richard Orr
U.S. Department of Agriculture; National Invasive Species Council

International Representatives

Dr. Alain Berinstain
Space Exploration Program, Canadian Space Agency

Professor Akira Fujiwara
ISAS/JAXA

Dr. Andrew J. Parfitt
CSIRO Australia Telescope National Facility

Dr. Gerhard Schwehm
ESA/ESTEC

International Representatives (continued)

Dr. Michel Viso
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PLANETARY PROTECTION ADVISORY COMMITTEE (PPAC)
NASA Headquarters
Washington, DC
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MEETING ATTENDEES

Committee Members:

Noonan, Norine (Chair)	College of Charleston
Atlas, Ronald	University of Louisville
Budden, Nancy Ann	Naval Postgraduate School
Carr, Michael	U.S. Geological Survey
Cavanaugh, Colleen	Harvard University
Hunt, Debra	Duke University
Ladwig, Alan	Zero Gravity Corporation
Leonard, Debra	Duke University
Levy, Eugene	Rice University
Pieters, Carlé	Brown University
Priest, Susanna	Texas A&M University
Robinson, George	Robinson & Associates Law Offices, PLC
Rummel, John D. (Executive Secretary)	NASA Headquarters
Zoloth, Laurie	Northwestern University

Agency Representatives:

Klein, David	National Institutes of Health
Orr, Richard	U.S. Department of Agriculture; National Invasive Species Council

Space Science Advisory Committee Liaison:

Erwin, Douglas	Smithsonian Institution

International Representatives:

Schwehm, Gerhard	European Space Agency (ESA)
Viso, Michel	Centre National d'Etudes Spatiales

NASA Attendees:

Adler, Mark	NASA/JPL
Buxbaum, Karen	NASA/JPL
Crisp, Joy	NASA/JPL
Dantzler, Andrew	NASA Headquarters
Diaz, Al	NASA Headquarters
Lavery, Dave	NASA Headquarters
McCuistion, Doug	NASA Headquarters
Meyer, Michael	NASA Headquarters
Norris, Marian	NASA Headquarters
Tahu, George	NASA Headquarters

Other Attendees

Katt, Robert	INFONETIC
Noble, Sarah	U.S. House of Representatives Science Committee Staff
Stabekis, Pericles	Windermere
Steele, Andrew	Carnegie Institution of Washington
Whitney, Pamela	National Research Council

PLANETARY PROTECTION ADVISORY COMMITTEE (PPAC)
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1. John D. Rummel, Office of Planetary Protection, NASA. *Planetary Protection Update to the Planetary Protection Advisory Committee*. February 8, 2005.
2. Gerhard H. Schwehm. Head of Planetary Missions Division, ESA Directorate of the Scientific Programme. *Results from Mars Express and Cassini/Huygens. Status of Planetary Protection Activities in ESA.*
3. Jean-Pierre LeBreton, Huygens Mission Manager/Project Scientist. *Huygens Mission Highlights*. RSSD Seminar, 28/01/2005. *The Mars Exploration Program: Still Following the Water*.
4. Doug McCuistion, Director, Mars Exploration Program. *The Mars Exploration Program: Still Following the Water*.
5. Andrew Dantzler, Acting Director, Solar System Division, NASA Science Mission Directorate. *Solar System Exploration*. January 2005.
6. Pam Whitney, Senior Program Officer, Space Studies Board, National Research Council. *PREVCOM Status and Update. NASA Planetary Protection Advisory Committee. February 8, 2005.*
7. Michael Meyer, MSL Program Scientist. *Mars Science Laboratory—Overview*.
8. Mark Adler. MSR Pre-Project Manager, Jet Propulsion Laboratory. *Mars Sample Return Pre-Project.*
9. Mark Adler. MSR Pre-Project Manager, Jet Propulsion Laboratory. *Mars Sample Return Receiving Facility.*
10. *Safe on Mars—Precursor Measurements Necessary to support Human Operations on the Martian Surface.* National Research Council Report, May 2002, Summary Briefing.
11. David Beaty and Noel Hinners. *Preparing for Humans—Developing Plans for a Martian Robotic Precursors Program.* December 14, 20004.
12. John D. Rummel, Office of Planetary Protection, NASA. *Planetary Protection and Humans on Mars?*